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INCLUDING ANISOTROPIC INFORMATION OF TRABECULAR BONE USING IMAGE REGISTRATION

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INTRODUCTION

Image-based modelling is a popular approach to perform patient-specific biomechanical simulations. Accurate modelling is critical for orthopaedic application to evaluate implant design and surgical planning. It has been shown that the bone strength can be estimated from the Bone Mineral Density (BMD) and the structure of the trabecular bone. However, these findings cannot directly be transferred to patient-specific modelling since only BMD values can be derived from calibrated clinical CT, but no information about the trabecular bone structure is accessible by the clinician.

The objective of this study is to propose a method that predicts the structure of the patient's trabecular bone using a template µCT image and image registration.

METHOD

Our proposed approach consists of morphing the bone architecture extracted from the µCT of a cadaveric patella to the patient's clinical CT. As µCT scans can be very large, applying the non-rigid image registration is extremely demanding in terms of computational resources and is practically intractable. Instead of using the original µCT images, we down-sampled the µCT of the template patella and then registered the new image to the clinical image. The registration was performed in three steps. First, a coarse rigid registration was applied, then an iterative affine registration with "Normalized Mutual Information" metric, was performed and finally a non-rigid registration using a Bspline registration (elastix; Klein, 2010) was applied to the images. In the next step, the resulting deformation fields were applied to the original high-resolution µCT image. The anisotropic information was then extracted from this high-resolution registered image.

We evaluated the mechanical outcome of the proposed method by comparing the finite element (FE) strength calculated for bones, where the material properties were assigned to the mesh i) using anisotropic material from the original µCT (ground-truth) ii) anisotropic properties from the registered image and iii) using an isotropic material model. Physiological loads were applied to these models. Bone strength as well as failure were evaluated.

RESULTS

We propose to test the method on two different bone anatomies, patella and femur. CT and µCT of 10 patellae and 10 femurs from different donors were acquired. From each database one bone was chosen as a reference and the other bones were defined as test samples.

The registration accuracy was high and the morphed image provided a good approximation of the trabecular bone structure in the patient's bone (Fig. 1). Our method predicted the displacement and force values at failure with 2.7% and 3.8% error respectively, while predictions obtained with an isotropic material results in error of 7.4% and 6.5%.

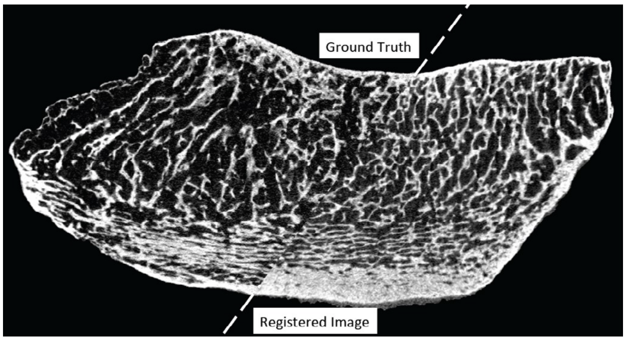

Figure 1: Typical result of the image registration. The ground truth µCT scan and the registered image are overlapped.

DISCUSSION

The results showed that our method improves the bone strength calculated with FE compared to an isotropic material model. It is possible to adapt this method to use several bones as reference, for instance using one reference for male and one for female bone, which can improve the prediction results. Exploring the impact of the selection of the reference bone is part of our future research.

REFERENCES

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